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RECOVERY OF VEGETATION IN THE ASH ERUPTED BY VESUVIUS IN 79

(*Concluded from page 104*)

We have observed that spontaneous vegetation from seedlings, even when hampered by a hard crust, was growing in depressions in deep ash deposits within five years after the ash had been erupted, and that, when it was not hampered by a hard crust, it had made rapid progress.

At the time that the Soufrière was in a state of eruption, Mt. Pelé on the neighboring island of Martinique also entered into a period of eruptive activity. An emission of burning volcanic ejecta from this volcano in May, 1902 destroyed the whole town of St. Pierre and 30,000 persons in a few minutes[79]. At the time of the eruption no attempt was made to estimate the depth of the volcanic ejecta, but in 1915 Dr. Edmund Otis Hovey stated that the depth of the ash on the summit plateau of Mt. Pelé, which prior to the eruption had been the basin of a small lake or pond of fresh water, varied from ten to fifty feet[80]. A chemical analysis of this ash (see Table I, in note 35, above) showed that it contained about the same amount of potash, phosphorus, and calcium as did the ash of the Soufrière[81]. After Dr. Hovey visited Mt. Pelé in 1908, he made the following general comments in regard to vegetation at that time[82]:

> ...many protected places and gullies where moisture has stayed longer than elsewhere have given vegetation a chance to start, and grass and bushes have crept half way up the south side of the mountain. The new ash resists decomposition into soil, wherever it remains dry or is well drained, hence vegetation is slow to take root in it....

Further on he stated[82a]:

> ...The moisture of so much cloud has induced moss to grow over the surface of the summit plateau (the basin of the Lac des Palmistes), and grass grows in the new ravines and in the crevices of the bombs and other boulders....

He commented on the fact that at that time the people were afraid of the volcano and the town of St. Pierre had not been rebuilt, although it was the natural outlet for a rich agricultural section[82b].

In 1915, after he had again visited Mt. Pelé, he stated[83] that

> ...even the rocks of the new cone are more or less thickly coated with moss, while the side and top of the old cone are covered with grass, ferns and bushes, in addition to moss and lichens. On the summit plateau we found an abundance of red raspberry bushes bearing flowers and green and ripe fruit.

Dr. Hovey commented on the fact that at this time on the east side of the mountain vegetation had progressed to the extent that the forest had begun to reestablish itself. However, the southwest side of the mountain still remained bare. Dr. Hovey believed that the lack of vegetation on this side of the mountain was due to the fact that the ash and the pumice were too porous to hold the necessary water. He also stated that at this time St. Pierre had a population of about 200 inhabitants[84].

Inasmuch as Dr. Hovey was simply reporting the return of vegetation, he made no distinction between that which might have returned through old roots which were uncovered after the tropical rains had washed the ash away, and that which might have returned through the development of seedlings. However, we may conclude that the raspberry bushes which were growing on the summit plateau in 1915 had developed from seedlings growing in volcanic ash, inasmuch as the plateau was covered at that time with ten to fifty feet of ash, and, previous to the eruption in 1902, had been the basin of a fresh water lake.

Two studies have been made of the return of vegetation on the island of Krakatau, which is located near Java, after the volcanic eruption of 1883 completely covered the island with pumice and ash. The first study was made by Monsieur M. Treub, who visited the island three years after the eruption. He stated that the volcanic ejecta which were erupted in 1883 varied in depth from one to about sixty meters[85]. At that time (1886) he found eleven different kinds of ferns, which represented the greatest part of the new vegetation, and several flowers[85a]. Because of the depth of the ejecta, he believed that these plants had not grown from old roots sending up shoots through the ash, but from seedlings[85b]. He also stated that there was no shade on the whole Island and that all seeds

[79]Report by Robert T. Hill on the Volcanic Disturbances in the West Indies, The National Geographic Magazine 13 (1902), 223–267, especially 249.

[80]Edmund Otis Hovey, Volcanoes of the Lesser Antilles: Observations on the Present Condition of the Active Volcanoes of Martinique, St. Vincent and Guadeloupe, The American Museum Journal 15 (1915), 254–255, especially 254.

[81]This chemical analysis was made by W. F. Hillebrand and was published in Diller, The National Geographical Magazine 13 (1902), 291 (see note 69, above).

[82]Edmund Otis Hovey, Ten Days in Camp on Mt. Pelé, Martinique: The Volcano Six Years after the Great Eruption, Bulletin of the American Geographical Society 40 (1908), 662–679, especially 673.

[82a] *Ibidem*, 678.

[82b] *Ibidem*, 666.

[83]Hovey, The American Museum Journal 15 (1915), 254 (see note 80, above).

[84]*Ibidem*, 254–255.

[85]Melchior Treub, Notice sur la Nouvelle Flore de Krakatau, Annales du Jardin Botanique de Buitenzorg 7 (1888), 213–223, especially 215.

[85a] *Ibidem*, 218–219. [85b] *Ibidem*, 215.

and plants were exposed to the hot sun[85c]. A chemical analysis of this ash (see Table I, in note 35, above) shows that it contained about the same amount of potash as the ash of Mt. Katmai, but no phosphorus[86]. Since this analysis was made several years ago, the methods of analysis in vogue at that time may account for the fact that no phosphorus or soluble salts were found.

The second study was made by Herr O. Penzig, who visited the island in 1897, fourteen years after the eruption. He found high grass, and lists forty-seven different "Gefässpflanzen" which he observed on the island of Krakatau[87].

Since plants have been known to send new shoots up through a covering of three feet of ash, we cannot be absolutely sure that all the vegetation which M. Treub observed was derived from new seedlings. However, since ferns made up a large part of this vegetation and ferns were among the first forms of vegetation noticed in the deep ash deposits made by the Soufrière of St. Vincent, it is probable that some, if not all, of this vegetation had sprung from new seedlings.

In summing up the results obtained from these studies of spontaneous revegetation in volcanic ash, we may state that we know definitely that revegetation in ash has taken place at any time between three and eighteen years after an eruption, the difference in time depending on the physical condition of the ash. When the ash was loose and not too well drained, revegetation was noted in protected places within three years after the ash was erupted; when the ash was crusted, revegetation was noted in depressions in the crust within six years after the eruption; when the ash was well drained and compact, revegetation took place in the neighborhood of eighteen years.

The ejecta which were erupted by Vesuvius in 79 we shall now consider from the point of view of their chemical composition and of their physical formation. We have no chemical analysis of the ash which was erupted at that time, but we do have chemical analyses of the lapilli and the pumice of 79. The analyses of these lapilli and of the pumice will not give us the exact content of the ash which was erupted at the same time, but there is usually a similarity in composition between different forms of ejecta thrown out by a volcano during one of its eruptions[88]. Consequently the chemical analyses of the lapilli and the pumice of 79 should give an indication of the contents of the ash of 79. An analysis of the white lapilli at Pompeii which were erupted in 79 has been made by Professor A. Lacroix[89] (see Table I, in note 35, above), and an analysis of the pumice at Pompeii which was erupted in 79 has been made by Professor Eugenio Casoria[90] (see Table I). Both analyses show that the lapilli and the pumice contained an unusually high content of potash (K_2O), together with calcium, magnesium, iron, and sulphur, all elements needed for plant life[91]. Professor Casoria's analysis shows the presence of phosphorus (P_2O_5)[92]. Nitrogen, the only other element needed for plant life, was, of course, absent, as it is from all volcanic ash. How fertile these ejecta were for the growth of vines can be determined from a consideration of the following figures. Professor E. Chancrin states that a soil which is rich in satisfying food elements for vines contains, to 1,000 grams of earth, 1 gram of nitrogen, 1 gram of phosphorus, and 2 grams of potash[93]. Consequently the pumice which was erupted in 79 (and in all probability the ash) contained at the time of its eruption about half as much phosphorus as is needed in a rich soil for vines and over forty-five times as much potash. These analyses of Vesuvian ejecta of 79 do not disclose to us the water soluble elements of the erupted materials. Water soluble elements are, of course, essential to plant growth, but the insoluble elements are also of importance, for the process of weathering gradually changes small portions of insoluble elements into soluble form and so makes them available for plant life[94].

What soluble salts were likely to be present in the ejecta from Vesuvius in 79? It was not until 1872 that it was learned that soluble elements were present in volcanic ejecta. At that time Professor A. Scacchi first discovered the presence of these soluble elements, usually referred to as soluble salts, in the ash erupted by Vesuvius[95]. After the outbreak of Vesuvius in 1906 Professor Casoria made a special study of the soluble salts contained in the ejecta of that eruption. It is only through a study of the soluble salts contained in the

[85c] *Ibidem*, 220. [86] *Ibidem*.

[87] O. Penzig, Die Fortschritte der Flora des Krakatau, Annales du Jardin Botanique de Buitenzorg 18 (Second Series, Volume 3, 1902), 92–113, especially 105–108.

[88] See Frederick William Rudler, the article Volcano, in The Encyclopaedia Britannica[11], 28.178–192. On page 181 he states that volcanic cinders (in which he includes lapilli), sand, ashes, and dust are but varied forms of solidified lava. When he is discussing lava on page 183, he states that it had been thought that in the course of a single long eruption or series of eruptions the character of the lava may vary to some extent. He continues by saying that it has been repeatedly proved that this is not usually the case. For the likelihood of error in the only described case of lavas of different composition issuing from the same volcanic pipe at the same time see Reginald Aldworth Daly, Igneous Rocks and the Depths of the Earth, 350–351 (New York, McGraw-Hill Book Co., 1933). See Immanuel Friedlaender, Physics of the Earth, I, Volcanology, 43 (Bulletin of the National Research Council, No. 77, Washington, D. C., 1931). For comments on the sensibly uniform chemical composition of the lava and ash which were erupted by Vesuvius in 1906 see Sir H<enry> J<ames> Johnston-Lavis, The Eruption of Vesuvius in April, 1906, The Scientific Transactions of the Royal Dublin Society, Series II, Volume 9 (1905–1909), 139–200, especially 173–174. For the uniform chemical composition of the lava throughout the eruption of 1906 see A. Lacroix, Les Produits Laviques de la Recénte Éruption du Vésuve, Comptes Rendus de l'Académie des Sciences, Paris, 143 (1906), 13–18, especially 14. For an opposing opinion see Frank Wigglesworth Clarke, The Data of Geochemistry[4], 300 (Bulletin of the United States Geological Survey, No. 770, Washington, Government Printing Office, 1924).

[89] A. Lacroix, Sur la Constitution Pétrographique du Massif Volcanique du Vésuve e de la Somma, Comptes Rendus de l'Académie des Sciences, Paris, 144 (1907), 1245–1251, especially 1249.

[90] Eugenio Casoria, Sulle Alterazioni Chimiche che Subiscono le Lave Vesuviane a Contatto delle Acque Marine, Annali della Regia Scuola Superiore di Agricoltura di Portici, Serie Seconda 6 (1906), 1–10, especially 8.

[91] See Thatcher, Crops and the Soil, 7–10 (see note 36, above).

[92] For many years the chemical analyses of the volcanic ejecta from Vesuvius did not show the presence of phosphorus pentoxide (P_2O_5). In 1882 Leonardo Ricciardi, Sulla Origine delle Ceneri Vulcaniche e sulla Composizione Chimica delle Lave e Ceneri delle Ultime Conflagrazioni Vesuviane (1868–1882), La Gazzetta Chimica Italiana 12 (1882), 305–328, especially 307 and 324, showed the presence of phosphorus pentoxide (P_2O_5) in Vesuvian ejecta and gave his method of determining it. Since that time most analyses of recent ejecta from Vesuvius have shown the presence of phosphorus. However, an examination of Table I in note 35, above discloses that Professor Lacroix's analyses of the ejecta erupted by Vesuvius in 1906 show consistently less phosphorus than Professor Casoria's analyses of the same type of ejecta (for these analyses see page 1249 of the article named in note 89, above).

[93] E. Chancrin, Viticulture Moderne, 226 (Paris, Hachette, 1919).

[94] Thatcher, Crops and the Soil, 12–13 (see note 36, above).

[95] A. Scacchi, Sulla Origine della Cenere Vulcanica, Rendiconto dell' Accademia Scienze Fisiche e Matematiche, Societá Reale di Napoli 11 (1872), 180–191.

recent ejecta of Vesuvius that we shall be able to gain any knowledge of the soluble salts which the ejecta of 79 probably contained. Professor Casoria found the following amounts of soluble salts in samples of various ejecta which were erupted in 1906[96]: red ash, 3.219%; gray ash, 2.626%; lapilli, 2.115%; lava, 0.395%. Professor Casoria then analyzed sample specimens of 100 grams of the *soluble elements* which were present in each of these forms of ejecta. These analyses I am giving below[97]. For the analyses of the insoluble elements of these ejecta by Professor Casoria see Table I (in note 35, above)[98].

TABLE II

	Red Ash at Portici	Gray Ash at Portici	Lapilli at Ottajano	Lava at Boscotrecase
Ca (Calcium)	8.339	9.334	8.090	0.945
Mg (Magnesium)	1.292	1.759	2.753	——
K (Potassium)	3.768	6.048	8.257	12.758
Na (Sodium)	22.116	18.047	17.970	30.395
Mn (Manganese)	0.657	0.681	0.539	——
Cl (Chlorine)	34.520	32.977	47.319	20.136
SO_4 (Residue of sulphuric acid)	29.520	31.150	15.064	4.723
SiO_2 (Silica)	0.079	0.026	——	——
CO_2 (Residue of carbonic acid)	——	——	——	30.749
	100.291	100.022	99.992	99.706

The amounts are indicated in terms of grams.

From these figures we can compute that the red ash contained 0.12% of water soluble potassium, the gray ash contained 0.16% of water soluble potassium, the lapilli contained 0.17% of water soluble potassium, and the lava contained but 0.05% of water soluble potassium. The amount of water soluble potassium contained in the lava (0.05%) is the same as the amount of water soluble potash contained in the ash of Mt. Katmai. As can be observed, water soluble potassium was present in all forms of ejecta which were erupted by Vesuvius in 1906. In fact, the ash and the lapilli contained, in soluble form, calcium, magnesium, and sulphur, in addition to the potassium, all elements necessary for plant growth[99]. I might add here that phosphorus (P_2O_5) in its natural state is never soluble in water[100]. These studies of the ejecta of 1906 would lead us to believe that all forms of Vesuvian ejecta contain water soluble potassium, provided that the ejecta contain potassium in its soluble form. Consequently, since the lapilli and the pumice of 79 did contain a high content of potash, we have reason to believe that these ejecta, and in all probability the ash of 79, contained water soluble potassium.

From the studies of the return of vegetation in areas covered by volcanic ash which we have previously considered, it is apparent that the physical condition of the ash is an important factor in determining the speed with which revegetation takes place. Our knowledge of the physical condition of the ash which fell in 79 is, of course, limited. As I stated above, it is generally believed that the ash which fell at that time was accompanied by showers and that the ash, in consequence, fell in a moist condition[101]. This belief is supported by the perfection of the molds that have been found which indicate that the ash was both moist and fine[102]. That the ash which composed the top layer of ejecta of 79 was fine we already know from the description given by Sir Henry James Johnston-Lavis[102a]. Fine ash is more favorable to revegetation than other coarser forms of volcanic ejecta are. It has been pointed out that the fine ash which was erupted by the Soufrière retained water better than the gravelly ash did, and suffered more rapid decomposition, so that it was better able to support vegetation[103]. In addition the Mt. Katmai expedition noted that fine ash held the water soluble elements that are so vital for plant life longer than the coarser volcanic material did[104]. Consequently, from what we can learn of the physical condition of the ash of 79, there is no reason to believe that that ash presented undue handicaps to revegetation.

Unfortunately, we have extremely few data in regard to the revegetation that has taken place in the volcanic ejecta of Vesuvius in modern times. During the eruption of 1906, the ash fall, though heavy, spread over a wide territory and at no place reached any great depth[105]. At Ottajano, where the ash fall was heaviest, the depth of the ash varied from 0.55 meters to 1.20 meters[106]. Even here there was no indication that the ash did any great harm to vegetation. Either the farmers were able to remove a large part of the ash, or they planted their crops in the ash and fertilized them well. There is reason to believe that the latter method was followed to some extent, for Sir Henry James Johnston-Lavis observed some farmers at Ottajano early in May planting cabbages and lettuces in the ash which had fallen in April[107]. We do, however, have some information in regard to the revegetation that has taken place in the lava which was erupted in 1906. Signor Giacomo Rossi in 1929, twenty-three years after the eruption of Vesuvius in 1906, reported that, where the lava of that eruption had been subjected to trampling by man, it was supporting ferns and hepaticas in

[96]For the proportion of soluble salts in the red and the gray ash which fell at Portici in 1906 see Eugenio Casoria, Sulla Composizione Chimicha delle Ceneri Vesuviane Cadute a Portici nei Giorni 9 e 10 Aprile 1906, Annali della Regia Scuola Superiore Agricoltura di Portici, Serie Seconda 6 (1906), 1–11, especially 6.

For the proportion of soluble salts in the lava of 1906 at Boscotrecase and in the lapilli which fell at Ottajano in 1906 see Eugenio Casoria, La Lava di Boscotrecase ed il Lapillo di Ottaiano, Annali della Regia Scuola Superiore di Agricoltura di Portici, Serie Seconda 8 (1908), 1–14, especially 6 and 13.

[97]For the chemical analyses of the soluble salts extracted from the red ash and from the gray ash see Casoria, 6 (1906), 6 (see note 96, above).

For the chemical analyses of the soluble salts extracted from the lava and from the lapilli see Casoria, 8 (1908), 6 and 13 (see note 96, above).

[98]For the chemical analyses of the insoluble elements of the red and the gray ash see Casoria, 6 (1906), 8 (see note 96, above).

For the chemical analyses of the insoluble elements of the lava and of the lapilli see Casoria, 8 (1908), 5 and 8 (see note 96, above).

[99]Thatcher, Crops and the Soil, 8–10 (see note 36, above).

[100]Chancrin, Viticulture Moderne, 235 (see note 93, above).

[101]See the text connected with notes 19–20, above.

[102]Sir H<enry> J<ames> Johnston-Lavis, The Quarterly Journal of the Geological Society of London 40 (1884), 85 (see note 14, above).

[102a]*Ibidem*, 84–85.

[103]Hovey, The American Museum Journal 15 (1915), 255 (see note 80, above).

[104]J. W. Shipley, The Water Soluble Salt Content, the Ferrous Iron Content and the Acidity of Katmai Volcanic Ash, Scientific Results of the Katmai Expeditions of the National Geographic Society, Ohio Journal of Science 19 (1918–1919), 224–229, especially 229.

[105]Frank A. Perret, The Vesuvius Eruption of 1906, 37 (Washington, Carnegie Institution of Washington, 1924).

[106]Sir H<enry J<ames> Johnston-Lavis, The Eruption of Vesuvius in April, 1906, The Scientific Transactions of the Royal Dublin Society, Series II, Volume 9 (1905–1909), 139–200, especially 168.

[107]*Ibidem*, 189.

addition to moss and lichens[108]. Lava is notorious for the slowness with which it usually weathers into soil.

The question now arises whether there was likely to be sufficient moisture in the neighborhood of Pompeii in the first century to allow vegetation to take place in the ash as quickly as it took place in the areas considered in the foregoing studies. The Soufrière, Mt. Pelé, and Krakatau are all located in the tropics. Undoubtedly revegetation in the ash deposits made by these volcanoes would be favored by an abundance of moisture and sunlight, and by a growing season which lasts through the entire year. However, there is little variation between the amount of precipitation during the growing season at Kodiak, Alaska, and the precipitation in the Fall, Winter, and Spring, the period which is the best growing season in the region of Campania. The average amount of precipitation at Kodiak for the months of May, June, July, August, and September for the years 1899–1914 was 30.49 inches[109]. The average amount of precipitation during the Fall, Winter, and Spring in the Campanian region at the present time is 28.54 inches[110]. On the other hand, vegetation in Alaska has more moisture in the form of mist to draw upon and also has the benefit of winter precipitation[111]. As is stated above, the average of rainfall in the Campanian region is obtained from present-day figures. There is reason to believe, however, that climatic conditions in Italy in classical times were very similar to present-day conditions[112]. While vegetation in the region of Pompeii would have had to withstand a drought each summer, it would have had the benefit of a longer growing season than exists in Alaska. In addition, the vegetation in the ash of 79 would not have been subjected to such high winds as prevailed in Alaska. There the winds not only buffeted the young plants, but blew the ash about to such an extent that the ash-soil was extremely unstable[113]. Also the vegetation about Pompeii would not be so likely to be winter killed as were many of the young plants about Kodiak[114].

We have seen that revegetation took place in the ash of Mt. Katmai in Alaska in favorable situations within three years, and, in an unfavorable situation, within eighteen years after the ash was erupted. Also, we know that revegetation took place in the lava of Vesuvius within twenty-three years after its eruption—and lava lends itself much more slowly to decomposition than does ash. Consequently, it would seem that fifteen years would be a very fair estimate of the time required for such vegetation as hepaticas, ferns, and moss to appear in the ash which was erupted in 79.

How long a time must elapse after this spontaneous growth has once appeared in volcanic ash before the ash is able to support crop plants through the addition of humus we do not know. Unfortunately we have practically no data on this point. Professor Griggs[115] pointed out that careful observations of the humus supply would throw considerable light on the problem of revegetation in volcanic ash, but, so far as I know, no publication of such observations has been made up to the present time. The little information that we can gather in regard to spontaneous crop plants from the studies cited above is (1) that the ash from Mt. Pelé was supporting, on the summit plateau, an abundance of raspberry bushes thirteen years after the ash was ejected[116]; and (2) that the ash of Mt. Katmai supported the lupine, a leguminous plant, within three to four years after the ash was erupted[117]. In addition, it has been pointed out that the Mt. Katmai ash, when well fertilized, was able to support pasture grasses shortly after the ash had fallen[118].

The element which is lacking in all volcanic ash, and which is so vital for all plant growth, is nitrogen[119]. This element can be supplied through humus, natural fertilizer, which would include manure and green dressings, plants which supply nitrogen to the soil, and mineral or chemical fertilizer[120]. While the Italians of the first century utilized to some extent mineral fertilizer, such as marl[121], they relied chiefly on manure, green dressings, and plants such as the lupine and medic to fertilize the soil[122]. To have supplied the ash which fell in 79 with manure or mineral fertilizer in sufficient quantities to produce results would have been too costly for the Italians. In addition, there is the possibility that the mineral fertilizer which might have been chosen would not have supplied the ash with nitrogen, but rather with other elements which were already present in the ash in sufficient quantities for crop production[122a]. To grow medic, some humus would in all likelihood have had to be present. However, the lupine, which was used by the Italians in the first century to fertilize the soil[123], and which supplies the soil with nitrogen[123a] grew spontaneously in the Mt. Katmai ash three to four years after the ash had fallen[124]. Consequently there is the possibility that the lupine also grew spontaneously in the ash of 79, and so served the same purpose in supplying the soil with nitrogen as did the lupine in the ash of Mt. Katmai. It is unlikely, however, that any attempt would be made by the Italians to seed the area with lupines to improve the ash-soil until spontaneous vegetation had developed to such an extent that crop

[108]Giacomo Rossi, Il Vesuvio e La Biologia, L'Italia Agricola (Piacenza, Fascicule 2 [1928]; Fascicules 3 and 8 [1929]). My information concerning Rossi's work, to which I have not had access, is derived from Ottaviano Bottini, La Regione Vesuviana, Annali del Regio Istituto Superiore Agrario di Portici, Serie III, Volume 5 (1932), 269–317, especially 290.

[109]Griggs, Kodiak, 18.

[110]Ernst Knorz, Studien ueber die Regenverhältnisse Italiens, 16–19 (Wetzlar, Schnitzler, 1918).

[111]Griggs, Kodiak, 18–19.

[112]Ellen Churchill Semple, The Geography of the Mediterranean Region, 99–100 (New York, Holt, 1931. Pp. viii, 737).

[113]Griggs, Kodiak, 37; Griggs, Katmai Valley, 338.

[114]Griggs, Kodiak, 50.

[115]Griggs, Katmai Valley, 342.

[116]Hovey, The American Museum Journal 15 (1915), 254 (see note 80, above).

[117]Griggs, Katmai Valley, 325; Griggs, Kodiak, 49.

[118]Griggs, Kodiak, 36.

[119]Thatcher, Crops and the Soil, 7–8 (see note 36, above).

[120]Thatcher, Crops and the Soil, 13 (see note 36, above); G. S. Fraps, Maintaining Soil Fertility, in Chamberlain, Chemistry in Agriculture, 92–105, especially 97–98 (see note 36, above); Chancrin, Viticulture Moderne, 231–234 (see note 93, above).

[121]Pliny, Historia Naturalis 17.42; Columella 2.16.4.

[122]Varro, Res Rusticae 1.23.3, 38.1–3; Columella 2.10.1, 11.2, 15.1–6, 16.5–6.

[122a]Kenneth C. Bailey, The Elder Pliny's Chapters on Chemical Subjects, Part I, 48–49, 169–171, note 106 (London, Edward Arnold and Co., 1929), states that most later writers agree that in many cases the niter to which Pliny refers was a carbonate or bicarbonate of sodium or potassium. He lists the few cases where Pliny might have been referring to a nitrate mineral. In but two of these cases (19.84, 143) does Pliny recommend that niter be used as fertilizer.

[123]Columella 2.10.1, 16.5–6.

[123a]Griggs, Katmai Valley, 325.

[124]*Ibidem.*

plants of various kinds would be attempted. The result would be that spontaneous vegetation would have to grow up and die down a sufficient number of times to supply the ash with some humus before the Italians would attempt to utilize the ash-soil.

But, at the very time that spontaneous vegetation was, in all likelihood, making headway in the ash, namely, in the early years of the second century, waste land in Italy was accumulating to such an extent that the phenomenon attracted the attention of the Emperors[125]. Under such conditions it was most unlikely that the Italians would carry on experiments in general agriculture in ash-covered waste lands. However, it is difficult to understand why no experiments were made with vines, particularly since the region about Pompeii had been famous for its wines before the eruption of 79[126]. It was known that vines did flourish on poor and stony soil[127]. Also it would seem likely, if we consider the probable content of the ash of 79, that, if the ancient method of fertilizing the roots of the vine had been employed, the vine would have been able to survive in the ash[128]. In addition, it can be pointed out that men in those days realized that even large quantities of volcanic ash might, in the end, prove beneficial to viticulture, for, when he is speaking of Catana, Strabo says[129]:

> ...According to Poseidonius, when the mountain is in action, the fields of the Catanaeans are covered with ash-dust to a great depth. Now although the ash is an affliction at the time, it benefits the country in later times, for it renders it fertile and suited to the vine, the rest of the country not being equally productive of good wine....

Strabo also thought that the fertility of the land about Vesuvius was due to the former activity of the volcano[130]:

> ...Above these places lies Mt. Vesuvius, which, save for its summit, has dwellings all round, on farm-lands that are absolutely beautiful. As for the summit, ... these masses of rock looking as though they had been eaten out by fire; and hence one might infer that in earlier times this district was on fire and had craters of fire, and then, because the fuel gave out, was quenched. Perhaps, too, this is the cause of the fruitfulness of the country all round the mountain; just as at Catana, it is said, that part of the country which had been covered with ash-dust from the hot ashes carried up into the air by the fire of Aetna made the land suited to the vine ....

If we consider these facts, we might expect persons who were interested in viticulture to show special interest in experimenting with vines in the ash which covered the region about Pompeii. While the results of these experiments might have been disappointing at first, each year, as new humus was added to the soil, the results should have been more and more satisfactory.

But there is no indication that any such experiments were made; if they were made, they were carried on by small peasant proprietors who lacked the capital to engage in viticulture on a large scale[130a]. Nor was the city of Pompeii rebuilt. Whether fear of Vesuvius in any way affected the development of this area is not known. In 1908 Dr. Hovey spoke of the fact that men were afraid of Mt. Pelé, and he thought at that time that the fear of the volcano was responsible for the fact that St. Pierre had not been rebuilt, although it was the natural outlet for a rich agricultural region[131]. But in 1915, when vegetation was recovering, about 200 persons were living in St. Pierre[132]. At the present time the town of St. Pierre has a population of 3,090 inhabitants[133]. There is no indication that subsequent eruptions of Vesuvius, or Mt. Etna, have prevented men from building towns close to those volcanoes.

Professor Rostovtzeff believes that Pompeii was not rebuilt, first, because of the emancipation of the provinces, which led to a general decline of agriculture in Italy[134], and secondly, because of the loss of the port which was occasioned by a recession of the sea and consequent raising of the coast line during the eruption of the volcano and attendant subterranean dislocations[135]. On the other hand, Professor Frank insists that the first reason given by Professor Rostovtzeff is not applicable because the general decline of agriculture in Italy does not enter into the discussion of the purely local question of Pompeii, where "One cannot raise vineyards on top of thirty feet of loose, dry cinders"[136].

When we consider Professor Frank's statement, two things should be taken into account. First, Professor Frank overlooks the four and a half feet or more of fine ash which covered the coarser ejecta and in which revegetation would have had to take place[137]. Ash, as has been pointed out, lends itself to revegetation more quickly than coarser volcanic material does[138]. Secondly, there is evidence that volcanic ash can support fruit-bearing bushes within a comparatively short time after that ash has fallen. For example, raspberry bushes

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[125]Rostovzev (= Rostovtzeff), Storia Economica...., 412 (see note 2, above); Frank, An Economic History of Rome[2], 440–441 (see note 2, above).

[126]John Day, Yale Classical Studies 3 (1932), 169 (see note 3, above).

[127]Pliny (Historia Naturalis 17.31) speaks of the Punic grapes that ripened on the rocks. See A. I. Perold, A Treatise on Viticulture, 14–25 (London, Macmillan, 1927), for a discussion of the most favorable soil for vines at the present time. On page 16 he states that the most famous vines in France are raised on stony soil. On page 25 he points out that, under favorable climatic conditions, few agricultural crops will succeed where the vine will not thrive.

[128]Columella 3.15.5, 4.8.3.

[129]I have quoted The Loeb Classical Library version of Strabo 6.2.3.

[130]I have quoted The Loeb Classical Library version of Strabo 5.4.8.

[130a]It is uncertain whether Domitian's edict, which forbade the planting of new vineyards in Italy and ordered the destruction of half the vineyards under cultivation in the provinces, was continued in force in Italy by later Emperors. In this connection we know that Trajan and Hadrian restricted the planting of new vineyards on waste lands of the imperial estates in Africa. For Domitian's edict see Suetonius, Domitianus 7.2, 14.2. For a discussion of this subject see Rostovzev (= Rostovtzeff), Storia Economica ...., 237, note 11, 421–422 (see note 2, above). Compare Frank, An Economic History of Rome[2], 427–428, 447 (see note 2, above), and A Commentary on the Inscription from Henchir Mettich in Africa, The American Journal of Philology 47 (1926), 153–170, especially 164.

[131]Hovey, Bulletin of the American Geographical Society 40 (1908), 666 (see note 82, above).

[132]Hovey, The American Museum Journal 15 (1915), 254 (see note 80, above).

[133]Rand McNally Commercial Atlas[66], 530 (New York, Rand McNally, 1935).

[134]Rostovzev (= Rostovtzeff), Storia Economica...., 232 (see note 2, above).

[135]Rostovtzeff, Out of the Past of Greece and Rome, 52 (see note 2, above).

[136]Frank, An Economic History of Rome[2], 414 (see note 2, above).

[137]Ruggiero, Pompeii...., Plate II (see note 6, above).

[138]See the text connected with notes 103 and 104, above.

grew on top of ten to fifty feet of volcanic ash thirteen years after that ash was erupted[139].

It seems fairly certain that during the early years of the second century, when in all likelihood the ash-covered fields about Pompeii were being clothed with spontaneous vegetation, Italy was beginning to suffer from a decline in agriculture. Professor Frank[140] believes that soil exhaustion, induced by over-cropping and by the tenant system, was responsible for the decline. Professor Rostovtzeff[141] believes that the economic decline in Italy was brought about by the emancipation of the provinces. This emancipation caused Italy to undergo keen competition in the home and provincial markets, which resulted in a decline of commerce and industry in Italy. As a consequence, the Italian city bourgeoise, who engaged in commerce and industry and, in general, carried on scientific agriculture, suffered financial ruin. Their situation was further aggravated by an overproduction of wine in Italy[142]. The result was that they gradually lost their agricultural holdings to the large capitalist. The large capitalist in Italy, he believes, found the production of grain, when it was carried on by numerous tenants, much less risky and almost as profitable as the growth of vines, which required much more scientific care[143].

If we return to a consideration of the reason why Pompeii was not rebuilt and the agricultural land surrounding it was not again developed, we find that Professor Frank's explanation, namely, that the ash prevented it, does not apply after the early years of the second century. As I have shown, by that time viticulture, particularly, could probably have been carried on successfully in the region of Pompeii. Why did this revival never occur? First, the loss of the local market at Pompeii would have been a severe handicap for any attempt to restore the prosperity of the region. The large number of small wine shops that have been excavated in Pompeii shows that a considerable amount of wine must have been sold locally[144]. Secondly, since Pompeii had served as a port for certain smaller towns of the interior, the local market derived much of its business from adjacent regions[145]. However, subterranean convulsions, which accompanied the eruption of Vesuvius in 79, brought about an elevation of the coast lands so that Pompeii was no longer located on the coast[146]. In addition, the great amount of ejecta erupted by the volcano at that time brought about a change in the course of the river Sarno, so that it no longer flowed near the city[147]. Inasmuch, then, as Pompeii was not a port-town after 79, it would not have been able to profit from business relations with towns of the interior. Thirdly, the great increase, during the first and the second century, in the number of small landholders who were being added to the proletariat of various cities and towns in Italy brought about a diminished demand for wine and oil[148]. Pompeii would, therefore, have had difficulty in regaining a market in Italy for its products. This situation was probably aggravated by the loss of the markets which Italians had served before the second century and by the increased competition which Italians encountered in the provinces[149]. Fourthly, the impoverishment of middle-class landowners and the growth of the *latifundia* deprived the region of Pompeii of the class that had been most interested in scientific agriculture[150]. But, in Africa, where the *latifundia* were widespread, waste lands were being developed along scientific lines[151]. Why, then, was the waste land about Pompeii not developed? Ultimately, it must have been because of the general decline of vital economic forces which were operative in Italy, not only a decline of agriculture, but also of other forms of economic endeavor.

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[139]Hovey, The American Museum Journal 15 (1915), 254 (see note 80, above).

[140]Frank, An Economic History of Rome[2], 479–480 (see note 2, above).

[141]Rostovzev (= Rostovtzeff), Storia Economica . . . ., 232 (see note 2, above).

[142]*Ibidem*, 235. [143]*Ibidem*, 239.

[144]John Day, Yale Classical Studies 3 (1932), 191 (see note 3, above).

[145]Strabo 5.4.8.

[146]Rostovtzeff, Out of the Past of Greece and Rome, 52 (see note 2, above).

[147]Mario Baratta, Il Porto di Pompei, Athenaeum 11 (1933), 250–260.

[148]Rostovzev (= Rostovtzeff), Storia Economica . . . ., 232 (see note 2, above).

[149]*Ibidem*, 235. [150]*Ibidem*, 232, 238.

[151]During the first and the second century the Romans cultivated olives on a large scale in Africa. See Rostovzev (= Rostovtzeff), Storia Economica . . . ., 238 (see note 2, above); Frank, An Economic History of Rome[2], 449–451 (see note 2, above). The Romans utilized land which at present is not cultivated and which has appeared useless, because of the small amount of rainfall, until recently, when the French discovered how the Romans were able to raise their large olive groves. See Tenney Frank, The Inscriptions of the Imperial Domains of Africa, The American Journal of Philology 47 (1926), 55–73, especially 69–73: T. R. S. Broughton, The Romanization of Africa Proconsularis, 4–6 (Baltimore, The Johns Hopkins Press, 1929). <For a review, by Professor Adolph F. Pauli, of this work see THE CLASSICAL WEEKLY 29.13–15. C. K.>.

SOPHOCLES AND EURIPIDES

While I have been reading the plays of Sophocles and Euripides I have noted some slight similarities which may not have been mentioned heretofore. Christ[1] points out a number of instances where one poet has influenced the other, or where Aeschylus has influenced both. Thus the noble Argive King in the Suppliants of Aeschylus is the prototype of the Sophoclean and of the Euripidean Theseus; the Egyptian herald is the forerunner of the character of Creon in the Oedipus at Colonus and of Copreus in the Heracleidae. Furthermore, the theme of suppliancy is found in the Oedipus at Colonus and in the Andromache, the Suppliants, and the Heracleidae. Christ might have added that the Oedipus, as well as the Heracles, opens with a scene of this sort, and that, in the Helen, Helen appears as a suppliant at the tomb of Proteus. Christ refers to Sophocles's use of the ***deus ex machina*** in the Philoctetes as an imitation of Euripides. The prologue and the method of treatment of the Trachiniae, he says, are also Euripidean.

Let us then proceed. The Heracles and the Trachiniae are often compared as dealing with the same hero. But I wonder if any one has discussed the likenesses between the Aias and the Heracles.

One is apt to think of Euripides when one reads of Aias amid the slaughtered cattle[2]. So it is that Euripi-

[1]Wilhelm Christ, Griechische Litteraturgeschichte, Part I, Sixth Edition, Revised by Wilhelm Schmid, 289, and note 3, 311 (Munich, Beck, 1912).

[2]In discussing the Ekkyklema, Reisch points out the similarity of situation in the Aias and the Heracles. See Wilhelm Dörpfeld and Emil Reisch, Das Griechische Theater, 245 (Athens, Barth and Von Hirst, 1896).

des's Heracles appears awaking from his madness after the slaughter of his wife and his children.

There are similarities of thought also in the two plays. The mere sight of Aias or of Heracles, it is said, would be sufficient to quell their enemies. In the Aias[3] we have:

ἀλλ' ὅτε γὰρ δὴ τὸ σὸν ὄμμ' ἀπέδραν,
παταγοῦσιν ἅτε πτηνῶν ἀγέλαι·
*μέγαν αἰγυπιὸν *δ' ὑποδείσαντες*
τάχ' ἄν, ἐξαίφνης εἰ σὺ φανείης,
σιγῇ πτήξειαν ἄφωνοι.

Euripides's verses are even more impressive[4]:

ἄρηξον, ἐλθέ,· καὶ σκιὰ φάνηθί μοι·
ἅλις γὰρ ἐλθὼν κἂν ὄναρ γένοιο σύ·
κακοὶ γάρ εἰσιν οἳ τέκνα κτείνουσι σά·

Perhaps he was here consciously improving upon the verses of Sophocles.

Aias, in despair and shame because of the foolish deeds he had done in his madness, thinks of suicide. His wife and the chorus try to cheer him and to deter him from his intent, but to no avail.

The striking scene at the end of the Heracles shows Theseus, King of Athens, helping his broken friend back to a manly, courageous outlook on life. Heracles, too, like Aias, thinks of suicide, but Heracles refrains from killing himself. Perhaps this is a criticism of Sophocles by Euripides.

The patriotic note, so strong in Aeschylus and in Euripides, is found in the Aias also. We hear of famous Salamis, and sacred Athens, and the wooded heights of Sunium[5].

Euripides, then, may perhaps be said to have copied the Aias in the Heracles and to have criticized it. Christ[5a] properly says that Sophocles wrote the Trachiniae to show how the theme should really be handled. If what I have said about the Aias and the Heracles is true, then perhaps Sophocles was retaliating. However this may be, we discover in the Trachiniae some reminiscences of Euripides.

Heracles rejoiced in the fair garment until the poison began to work, much as the daughter of Creon at first rejoiced in the poisonous garment and crown sent to her by Medea.

But a more striking resemblance to Euripides is to be found in the actions of Deianeira after she learns of the death of her husband through her unconscious fault. Going into the house she wept at the sight of all the familiar objects and of her dear servants. Then rushing into Heracles's room she prepared to die. Certainly this is borrowed from the description of Alcestis's last acts about the house before her death[6].

[3]Aias 167–171. I have used the edition of Lewis Campbell: Sophocles, Volume II (Oxford: At the Clarendon Press, 1881). I translate this passage as follows: 'When they have escaped thine eye, they chatter like flocks of birds. Yet, fearing the great vulture, if thou shouldst suddenly appear, straightway would they cower in silence, voiceless'.

[4]Heracles 494–496. I use the text presented by Gilbert Murray (Oxford Classical Text Series, 1913). I translate this passage as follows: 'Help, come! Appear to me though as a shadow. Thy coming would suffice, though thou shouldst be a dream. For they are cowards who would slay thy children'.

[5]Aias 596–598, 859–865, 1217–1222.

[5a]Christ, 283 (see note 1, above).

[6]Trachiniae 899–946, and Alcestis 152–198. Sophocles was evidently fond of the Alcestis, for in the Philoctetes we have another reminiscence: Heracles, the *deus ex machina*, speaks in the Philoctetes of piety in words that remind us of his words on hospitality at the end of the Alcestis. In Alcestis 1147–1148 we have *καὶ δίκαιος ὢν τὸ λοιπόν, Ἄδμητ', εὐσέβει περὶ ξένους*. In Philoctetes 1440–1441 we have *τοῦτο δ' ἐννοεῖσθ', ὅταν πορθῆτε γαῖαν, εὐσεβεῖν τὰ πρὸς θεούς·*

One further point deserves notice. Heracles is awakened by the anguished words of his son, Hyllus, in spite of the old attendant's attempt to preserve quiet. This type of scene is rather frequent in tragedy. We find it, also, in the satyr-play, the Cyclops. Odysseus invokes sleep to lull the Cyclops while his eye is being burned out. At the same time he tries to keep the cowardly satyrs still. But they persist in talking.

In the Heracles the chorus awake Heracles in spite of Amphitryon's attempt to hush them.

We find something similar in the Electra. Orestes and his attendants try vainly to hush Electra, who in the excess of her joy can not keep still, although there is danger of their being overheard[7].

Again we find the scene in the Orestes. Orestes, after a vision of the Furies, is sleeping, watched by his sister Electra. The chorus cannot be kept quiet, and finally wake him with the marvellous little lyric, *πότνια, πότνια νύξ*. Euripides here has imitated a lyric of the Philoctetes (827–832) where the chorus pray that sleep may descend upon the weary pain-smitten Philoctetes.

It is very hard to determine in all cases who said the thing first. But the influence of the poets upon one another is very evident.

We are almost tempted to imagine that Sophocles in the Trachiniae is laughing at Euripides's dramatic technique, for the Trachiniae has the Euripidean prologue, a poison scene like that of the Medea, an Alcestis-heroine, and a sleep-waking scene which may have originated with Euripides.

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THUCYDIDES 2. 8. 4

In Thucydides 2.8.4 we read: *ἐν τούτῳ τε κεκωλῦσθαι ἐδόκει ἑκάστῳ τὰ πράγματα, ᾧ μή τις αὐτὸς παρέσται.* This sentence occurs with a slight variation in 4.14.2. It is imitated in Livy 30.9.8 et in quo quisque cessaret prodi ab se salutem omnium rebatur. In the last two passages the sentence, exaggerated as it is in expression, fits into its context. In Thucydides 4.14.2 the reference is to the desperate mêlée round the ships at Pylos; in Livy the reference is to the eagerness of the Romans to bring the war in Africa to its final decision. But in Thucydides 2.8.4 the sentence as a description of the general feeling in Greece at the outbreak of war is surely excessively strained, and compares ill with the dignified opening of Thucydides's work. The passage is improved both in rhythm and in sense by the omission of this

[7]We might note in passing that, in the Electra, Sophocles perhaps borrows from Euripides the device of having the actors tell the audience the plan they propose to carry out, and of then letting the audience see the plan in action. It is very effective. Medea tells her plan to murder Creon's daughter (Euripides, Medea 364–409). Then we hear by messenger of the actual happening (1136–1230). The scene in the Electra of Sophocles (680–763) is the better because the attendant gives such an elaborate and thrilling story of Orestes's death. We knew what lie he was to tell, but not how well he would tell it, and so we are especially delighted at his rare gift of fabrication. The same technique is seen also in the Ion. The old slave's plan to murder Ion is made known to the spectators in advance (1029–1047). Then they hear of the event in the messenger's report (1122–1228).

sentence. Is it a gloss, due, perhaps, to a reader to whom *ἐπιλαμβανόμενοι* of 4.14.2 was recalled by *ξυνεπιλαμβάνειν* of 2.8.4?

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ARISTOPHANES, BIRDS 904–955

Perhaps it is because the joke is so obvious that it needs no explanation that no English or American commentator on the Birds of Aristophanes has pointed out that the episode of the poet in Birds 904–955 is only a specially elaborated form of the favorite jibe at 'frigid' versifiers. In the Acharnians (138–140) the frigidity of Theognis's drama at Athens causes a snowstorm in Thrace, by a reversal of natural law, but in the Birds the poet himself is the sufferer. Van Leeuwen, in his comment on 935, "nempe tam frigida carmina iactare non posset si satis celaret ipse", sees this, but the point is rather that the poems are so frigid as to chill even their author. The poet's plea for summer clothing rouses the pity of Peithetairos, who says (935), *ἔχε τὴν σπολάδα, πάντως δέ μοι 'ριγῶν δοκεῖς*. This, however, is a mere palliative. The frigid poet's last song is on a chilly theme (952–953):

Κλῇσον, ὦ χρυσόθρονε, τὰν τρομεράν, κρυεράν.
Νιφόβολα πεδία πολύπορά τ' ἤλυθον, ἀλαλαί.

On this Peithetairos comments in surprise (954–955):

Νὴ τὸν Δί', ἀλλ' ἤδη φέφευγας ταυταγί
τὰ κρυερά, τονδὶ τὸν χιτωνίσκον λαβών·

But *ψυχρὸς ὤν, ψυχρῶς ποιεῖ* is true of this poet, as of Theognis (Aristophanes, Thesmophoriazousae 170).

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REVIEW

Teocrito, Studio Critico. Ettore Bignone. Bari: Giuseppe Laterza e Figli (1934). Pp. 8, 388, 1.

Professor Bignone's verse translation of Theocritus has been known for some years[1]. It has a delicate, musical charm, partly Theocritean, partly its own, and on account of it a full expression of Professor Bignone's estimate of Theocritus must be gladly received. But Professor Bignone is still further equipped, by his work on other Hellenistic literature, poetry and prose, to determine the qualities which make Theocritus supreme among artistic writers who lived after the age of classical Greece, and before the rise of 'poets of history' under Rome. He considers Theocritus in a large historical context, referring aptly to political and cultural conditions in Sicily and Alexandria, and to the known facts of the poet's life; he compares the idylls with one another, accurately defining their individual characteristics of style and treatment, and with the work of other poets, earlier and later, especially poets who handled the same themes. His readiness to relate poetry to sculpture, both in his translation and in his critical book, is admirable and instructive. He shows that Theocritus had a true poet's power of perceiving and clearly presenting a varied and vital reality, without descents to mechanical processes, or any usual Hellenistic faults. Technical discussions are subordinated to literary criticism, but sometimes, as at Idylls 8.55–56, which Professor Bignone brilliantly translates, rendering well the Greek vowel sounds, by

ma sotto questo dirupo cantare, tinendoti in braccio,
mentre pascer le agnelle contemplo al siculo mar,

aesthetic judgment makes clear the solution of a technical problem. Professor Bignone's sense of poetry is refined and modern; but there is a sense in which he belongs to an older school of critics, more obviously descriptive than analytical. Accordingly, the length and the leisurely, though graceful, style of his book may well disguise the value of his thought. This should not deter those who love Theocritus from searching it, for the search will be rewarded.

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[1]Ettore Bignone, Gli Idillii di Teocrito,Tradotti in Versi Italiani, Con 13 Illustrazioni (Palermo and Elsewhere, Remo Sandron, 1924).